LIQUEFIED GAS STORAGE INSTALLATION

This invention relates to a liquefied gas gas storage installation.

Petrol, also known as gasoline, is the most widely used of all fuels in internal combustion engines. In view of the suspected adverse effect that exhaust gases from petrol-fuelled internal combustion engines have on the climate, alternative fuels are being investigated. These include permanent gases such as hydrogen and methane. It is desirable to store such gases underground in liquid state.

WO-A-02/64395 relates to a filling station for cryogenic media, in particular liquid and/or gaseous hydrogen under high pressure. The filling station includes at least one cryogenic liquid storage container located underground. The storage container in the form of a tank is located in an underground vault which may be sub-divided into several chambers. The storage tank may be located in one of these chambers, while liquefied gas pumps may be located in separate chambers.

The mere location of the pumps and the tank in different chambers does not, however, guarantee safe operation of the filling station. There is a particular problem that components such as valves inherently carry with them a certain risk of leakage.

According to the present invention there is provided an installation comprising a vault housing a liquefied gas storage tank, a chamber within the vault accessible to personnel, a liquefied gas filling pipeline leading to the gas storage tank, a liquefied gas supply pipeline extending from the storage tank through a vaporiser out of the vault, at least one first cabinet through which the liquefied gas supply pipeline passes, the first cabinet being located in the chamber and housing items of equipment in the liquefied gas supply pipeline which have an associated risk of leakage, a first extractor fan communicating

with the first cabinet, and means separate from the first extractor fan for changing the atmosphere in the chamber.

The installation according to the invention makes it possible to confine to cabinets within the chamber items of equipment that have an associated risk of leak while enabling any gas that does leak to be detected at an early stage to be extracted from the cabinets, and all desirable safety measures to be taken. As a result, the risk of creating hazardous conditions in the main atmosphere within the chamber is reduced. This risk is further reduced by appropriately ventilating the chamber.

The installation according to the invention is particularly suited for the storage of combustible liquefied gases such as natural gas, methane and hydrogen. Accordingly, the gas storage tank may be adapted to store a combustible liquefied gas.

Preferably, the said cabinet has associated therewith a sensor able to detect leakage of the gas and to generate a signal related to a particular condition of the atmosphere therein, the sensor being operatively associated with a second extractor fan communicating with the interior of the cabinet so as to increase the rate at which air is extracted therefrom. In one example, should the concentration of combustible gas in the atmosphere within the cabinet reach a chosen level, the second extractor fan is actuated so as to increase the rate at which air is extracted from the cabinet.

Preferably the installation according to the invention additionally includes at least one further cabinet, the further cabinet being located in the chamber and housing items of equipment associated with the gas storage tank that have a risk of leakage associated therewith, the interior of the further cabinet communicating with the first extractor fan.

There is preferably but a single vault, but in order to reduce the risk to personnel who from time to time may need to enter the chamber for servicing or other reasons, the vault preferably includes a bulkhead making a fluid tight engagement with the storage tank and defining one wall of the chamber, most of the storage tank being located within the vault but outside the chamber. Typically, more than 95% of the volume of the storage tank is located behind the bulkhead and thus outside the chamber.

A liquefied gas pump is typically located in the liquefied gas supply pipeline. The pump not only communicates with the storage tank but also with a purge gas pipeline which may, for example, communicate with a source of suitable purge gas which is neither combustible nor supports combustion, for example, nitrogen or helium, which is typically stored above ground and therefore outside the vault. The liquefied gas supply pipeline preferably has associated therewith at least one vent pipeline having a valve disposed therein, the vent pipeline communicating with a stack above ground.

The chamber preferably has at least one atmosphere sensor associated therewith. In one arrangement, an oxygen gas detector is provided in the chamber. Access to the chamber through, for example, a door is permitted only when the sensed oxygen concentration is within a chosen range.

The chamber preferably has associated therewith at least one fan as said means for changing the atmosphere therein. Preferably, the chamber has a roof in the form of a heavy-duty metal mesh through which air is able to pass out of the chamber into an upper shaft.

If desired, the gas supply pipeline may have a plurality of isolation valves located therein, each isolation valve being automatically operable on an unsafe condition being detected in the chamber or one of the first or further cabinets.

An installation according to the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of the installation illustrating the arrangement of the chamber and the cabinets;

Figure 2 is a schematic diagram illustrating the atmosphere management equipment associated with the installation, and

Figure 3 is a schematic process flow diagram illustrating the disposition of some of the valves deployed in the installation.

Referring to Figure 1 of the drawings, a hydrogen storage installation includes a vacuum-insulated tank (or vessel 2) for holding a volume of liquid hydrogen. The tank 2 is of conventional construction and configuration. It is generally cylindrical in shape with its main axis disposed horizontally. The tank 2 is located in an underground vault 4. The positioning of the tank 2 underground eliminates any risk of a catastrophic accident being caused by a land vehicle crashing into it, rupturing or otherwise breaching the tank, and setting fire to hydrogen spilling out of the rupture or breach.

The underground vault 4 has a floor 6 and a roof 8. A vertical bulkhead 10 divides the vault into two chambers 12 and 14. The tank 2 makes a gas-tight seal with the bulkhead 10. At least 95% of the volume of the tank 2 is located in the chamber 12. The remaining part of the tank 2 extends through the bulkhead 10 into the chamber 14. The tank 2 itself is mounted on vertical supports 16 extending upwards from a plinth 18 in the chamber 2. The tank 2 is installed before the bulkhead 10. Once the bulkhead 10 is fitted and sealed to the tank 2, access to the chamber 12 may be gained through a port located above ground to the rear of the tank 2. On the other hand, the chamber 14 is a ventilated room having an access opening 20 through which a ladder or

flight of stairs (not shown) passes, the ladder or flight of stairs extending from the floor 6 of the vault 4 to above ground.

The tank 2 has an inlet port connected to a pipeline for filling it with liquid hydrogen. For ease of illustration the inlet port and filling pipeline are not shown in Figure 1. A liquid hydrogen supply pipeline 22 extends from a region of the tank 2 within the chamber 14 through the chamber 14 and terminates in one or more buffer vessels 24 above ground. The pipeline 22 has a liquid hydrogen pump 35 and a liquid hydrogen vaporiser 37 disposed in it. Therefore, in operation, the buffer vessels 24 receive gaseous hydrogen from the pipeline 22. A hydrogen delivery pipeline 26 extends from the buffer vessels 24 to a gas dispenser 28. The gas dispenser 28 may be of a standard kind for charging a motor vehicle with a gaseous fuel and will include a hose 30 and a filling nozzle 32.

The liquid hydrogen supply pipeline 22 has various items of equipment disposed therealong which all have a tangible risk of leakage. All these items of equipment are arranged in three cabinets 34, 36 and 38 located in the chamber 14. Each cabinet has a door (not shown) which in its closed position permits exchange of atmosphere between the chamber 14 and the cabinets. In addition, there are three further cabinets 40, 42 and 44 housing valves and bursting discs and the like associated with that part of the tank 2 extending into the chamber 14. For ease of illustration, all the items of equipment housed in the cabinets 34, 36, 38, 40, 42 and 44 are not shown in Figure 1 apart from the liquid hydrogen pump 35 and the liquid hydrogen vaporiser 37. The cabinet 34 houses the liquid hydrogen pump 35. The liquid hydrogen pump 35 is typically a reciprocating positive displacement unit specifically designed for hydrogen service. The liquid hydrogen pump 35 has a thermosiphon associated therewith to enable the pump to be cooled to a suitable operating temperature. In one arrangement, actuated valves (not shown in Figure 1) on the pump suction and the vapour return to the tank 2 may be opened at a chosen time so as to allow liquid hydrogen to flow under

gravity into the pump 35 and return to the tank 2 by virtue of a thermosiphon effect. A timer circuit may be employed to inhibit actuation of the pump 35 for a chosen period after the start of the pump cooling operation. The pump 35 is typically driven by an electric motor 46 which is desirably located in the chamber 14 but outside the cabinets 34, 36, 38, 40, 42 and 44.

Once the pump 35 is actuated a valve (not shown in Figure 1) simultaneously opens in the liquid hydrogen supply pipeline 22, the valve typically also being located in the cabinet 34 and liquid hydrogen flows under high pressure to the liquid hydrogen vaporiser 37 which is located in the cabinet 36. The vaporiser 37 is typically of a kind which has an electrical heater associated therewith to provide sufficient heat to vaporise the liquid hydrogen and raise it to approximately ambient temperature or a temperature a little below ambient temperature. The vaporised, pressurised hydrogen passes through one or more high pressure control valves (not shown in Figure 1) which are positioned in the cabinet 38 together with suitable pressure relief and purge valves (not shown in Figure 1).

There are a number of different operating methods that can be used to charge a vehicle with gaseous hydrogen. In one such arrangement the vehicle is filled at approximately 350 bar. The first step is to equalise the pressure between the hydrogen storage facility on the vehicle to be filled (not shown in Figure 1) and the buffer vessels 24. Accordingly, valves (not shown in Figure 1) located above ground are operated to open the buffer vessels 24 and allow hydrogen to flow therefrom into the vehicle to be filled with the result that the pressure in the buffer vessels 24 is equalised with that in the storage facility of the vehicle being filled with fuel. The liquid hydrogen pump and the vaporiser are then operated to raise the pressure in the fuel storage facility of the vehicle to a chosen preferred operating pressure 350 bar. Once this pressure has been achieved and therefore no more hydrogen flows, the pump may be deactuated and the valves associated with the buffer vessels 24 closed.

The inventive nature of the installation according to the invention does not, however, reside in the operation of the pump and vaporiser, but rather in the disposition of the pump, vaporiser and valves in the cabinets and the arrangements made to keep the cabinets 34, 36, 38, 40, 42 and 44 properly ventilated.

The three cabinets 40, 42 and 44, the contents of which have not been described above, will now be discussed. The cabinet 40 houses a pressure raising coil, pressure raising valves and a back pressure valve, all conventionally arranged, which are preferably arranged to maintain the storage pressure in the tank 2 within a working range of 4 bar - 11 bar (absolute). The cabinet 42 houses vessel safety valves and bursting discs, all of a conventional nature, and all associated with the tank 2. The cabinet 44 houses liquid locks, vent and purge valves, all of a conventional nature and all associated with tank 2.

The arrangements for charging the atmosphere in the cabinets 34, 36, 38, 40, 42 and 44 are now described with reference to Figure 2 of the drawings. Each of the cabinets is provided with an outlet pipe 50 communicating in the chamber 14 with a main pipeline 52 which extends out of the chamber 12 into a ventilated fan room 54 located above ground. An extractor fan 56 is disposed in the pipeline 52 at a region of the latter which is situated in the fan room 54. The extractor fan 56 is operable to provide 60 atmosphere changes per hour in each of the cabinets 34, 36, 38, 40, 42 and 44. An auxiliary extractor fan (not shown) is preferably also provided which when actuated increases the ventilation rate in the cabinets 34, 36, 38, 40, 42 and 44 to 120 atmosphere changes per hour.

The extractor fans 56 may be operatively associated with various gas detectors. It is vital to ensure that the hydrogen concentration in any of the cabinets does not approach the lower explosive limit (LEL). In a typical arrangement, each of the cabinets 34, 36, 38, 40, 42 and 44 is provided with a

hydrogen detector (not shown) and a heat sensor (not shown). Normally, as mentioned above, the main extractor fan 56 is operated to provide 60 atmosphere changes per hour in each of the cabinets 34, 36, 38, 40, 42 and 44. Should a hydrogen concentration of even 10% of that at the lower explosive limit be detected in any of the cabinets, then the auxiliary extractor fan is actuated and an alarm is triggered. Should the hydrogen concentration detected in any of the cabinets continue to rise, then a fuelling operation would be ended and all flow control valves in the supply pipeline 22 closed.

The fan room 54 is also provided with a main ventilation fan 60 which provides a flow of air to main air pipeline 62 which extends from the fan room 54 to a region of the chamber 14 near the floor 6 and terminates in a header 64 having a plurality of air distribution outlets 66 arranged so as to give good air circulation. The region of the roof 8 of the vault 4 that bounds the chamber 14 is formed of a heavy duty steel mesh 68 so that air can pass therethrough.

The main ventilation fan 60 is operable to provide five atmosphere changes per hour in the chamber 14 in addition to the atmosphere changes in the cabinets. Its operation may however be augmented by an auxiliary ventilation fan (not shown in Figure 2) so as to provide ten atmosphere changes per hour. Generally, the higher rate of atmosphere change in the chamber 14 will be triggered whenever liquid hydrogen fuel is being delivered to the storage tank 2, whenever a vehicle is being refuelled with hydrogen from the storage tank 2, or if a hydrogen concentration of 10% of that at the lower explosive limit is detected in the chamber 14. (In view of the low density of hydrogen it is desirable to locate hydrogen detectors at the top of the vault 4.) The chamber 14 is typically also provided with oxygen sensors, carbon dioxide sensors and flame detectors. In the event of an emergency, the chamber 14 may be flooded with nitrogen or carbon dioxide or other gas which can act to extinguish a fire, although such systems are provided with an override to prevent their actuation whenever an operative is inside the chamber 14.

Although not shown in Figure 1 or Figure 2, the pump has a purge line which leads to a vent stack. Other vent lines associated with the supply pipeline 22 also lead to the vent stack. The vent stack and the cylinders of the pump are preferably continuously purged with nitrogen.

The above described installation confines parts that are liable to leak to cabinets which are well ventilated. Safe operation and maintenance of the installation is thereby facilitated.

Although the installation shown in the drawings has been described above in connection with the storage and delivery of hydrogen, it may alternatively be used to store and deliver natural gas.

Referring to Figure 3, the liquid hydrogen storage tank 2 typically has a plurality of fill lines 70 each with at least one automatically-actuated on-off valve 72 disposed therein. The pipeline 22 also has at a vicinity near its inlet a further automatically-actuated on-off valve disposed therealong. A similar valve 72 is also located in a liquid hydrogen return line 74 that terminates in the tank 2. Each of the pipelines conducting liquid hydrogen associated with the storage tank has at least one gas lock release valve 76, vent valve 78, and purge valve 80 associated therewith. As the function and operation of these valves is conventional, no further description of them is required. They are typically all located in one of the cabinets 42 and 44 (not shown in Figure 3).

The pump 35, vaporiser 37, liquid hydrogen fill lines 70, and the part of the pipeline 22 disposed in the cabinet 38 are all associated with nitrogen purge pipelines 84 that are able to be placed in communication with a source of nitrogen (not shown), typically a liquid nitrogen storage tank and associated liquid nitrogen vaporiser, both located above ground. The liquid hydrogen pump contains a plurality of sealed pumping chambers (not shown). The

seals minimise leakage of hydrogen from the pumping chambers to a "waste gas" chamber 86. This chamber 86 is typically purged continuously with nitrogen during operation of the pump 35. Typically, all the purge pipelines communicate with a vent stack (not shown).

The vaporiser 37 is another item of equipment shown in Figure 3 that is provided with a nitrogen purge pipeline 84. So are the valves located in the cabinet 38. Typically, all the valves in the pipeline 22 that are located downstream of the vaporiser 37 and can be positioned underground are located in the cabinet 38. These valves include a vent valve 90, a purge valve 92, and automatic on-off valves 94 which are operable to help draw hydrogen through the pipeline 22.

As shown in Figure 3, there are fifteen buffer vessels 24 provided. Each of these vessels is typically located above ground. Each buffer vessel 24 has an automatically operable on-off valve 96 associated therewith. The valves 96 can be opened and closed to enable the buffer vessel 24 either to receive hydrogen from the pipeline 22 or deliver it to the pipeline 26 which communicates with the dispenser 28 (not shown in Figure 3). An automatically-operable valve 100 is located in the pipeline 26 and may be opened whenever it is desired to deliver hydrogen to the dispenser 28.

The installation shown in Figure 3 is also provided with several manually operable on-off valves 102.